Yield Performance of Sesame (Sesamum indicum L.) Varieties at Different Levels of Plant Population in Optimum Moisture Areas of Western Tigray, Northern Ethiopia

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Abstract
The production of sesame (Sesame indicum L.), an important oil crop produced for export in Ethiopia, is affected by environmental and biotic factors as well as management practices. Determining the optimum plant population in optimum moisture areas for sesame is crucial to boost sesame productivity. A field experiment was conducted at Zuria-Dansha, in optimum moisture areas of western Tigray to evaluate yield performance of sesame varieties at different levels of plant population. The experiment was laid out in RCBD in factorial arrangement with three varieties of sesame (Gida-Ayana, Humera-1 and Hirhr) and four plant population (80,000, 124,444, 250,000 and 666,666 plants/ha) in three replications. The result revealed that varieties and plant population significantly differed in yield and yield related traits. The variety Gida-Ayana recorded maximum fertile capsules per plant, thousand seed weight, seed per capsule and oil content (%) while the local variety Hirhr recorded the least. The yield components like: fertile capsules per plant, seed per capsule and thousand seed weight were highest in the low plant population than highest plant population but oil content (%) was not affected by different levels of plant population. The highest seed yield was obtained from variety Gida-Ayana grown at 250,000 plants (10 cm × 40 cm) which significantly increases yield by 34.75% as compared with local variety Hirhr with the same plant population. Hence, it can be concluded that higher seed yield and oil content (%) of sesame could be obtained by using Gida-Ayana variety sowing at the plant population of 250,000 plants/ha (40 cm × 10 cm) under optimum moisture areas of western Tigray and similar agro-climatic conditions.
Keywords: Optimum moisture, performance, plant population, Sesame, Varieties, Yield
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1. Introduction

Sesame (*Sesamum indicum* L.) otherwise known as *sesamum*, member of the family *Pedaliaceae*, is one of the ancient oilseed domesticated and cultivated in tropical and sub-tropical parts of the world by man for the edible oil and medicinal purposes for more than 5000 years (Khan et al., 2009 and Umar et al., 2010). Though it is a controversy for the origin of sesame, it is believed to be originated in Ethiopia due to existence of both cultivated and wild types in the country (Wijnands et al., 2009). Ethiopia is one of the popular sesame producers in the world and the seed produced in western Tigray (Humera type) is highly competent in the world market by its desirable qualities in terms of color, taste and aroma (Taghouti et al., 2017). Sesame is used one of the main cash crops and the second export commodity, next to coffee in Ethiopia and plays significant role as source of rural employment and ensuring food-security of millions of people (Abebe, 2016).

The crop is grown under different environments which may affect its growth performance. Environmental and biotic factors (weed, disease and insect pest) as well as management practices are the main sesame production constraints. The environmental factors include temperature, rain fall and soil types. Areas with annual rainfall of 625-1100 mm, deep, well-drained, fertile sandy loams and temperature of >27^0c is the most conducive for sesame production (Geremew et al., 2012). The management practice on the other hand includes plant population, time of sowing, type and rate of fertilizers. The plant population per unit area plays a vital role in determining the final seed yield of crops (Malik et al., 2003) and types of sesame varieties that adapt for that particular area may also be critical to boost sesame production.

The productivity of sesame (607 kg/ha) in Tigray region is lower than the national average yield of 686 kg/ha (CSA, 2019) while in the optimum moisture areas of Western Tigray (specifically in the study area) is about 3.5 kg/ha - 4.5 kg/ha (personal communication with bureau of agriculture/BOA). However, sesame productivity can go up to 1000-1200 kg/ha under optimum agronomic cultivation (Ali et al., 1997). The low productivity of sesame in the study area might be due to cultivation of low yielding varieties and poor management practices like inappropriate plant density. Plant population is one of the agronomic management practices and manipulation of that could increase yield performances of sesame varieties. The effect of plant population on yield and yield components of sesame have been reported by several researchers. Kale et al., 2018 and Roy et al., 2009 reported that, inter and intra row spacing of 30 cm x 10 cm was obtained higher seed yield and yield components in sesame. However, the effect of sesame varieties planted in different plant population in optimum moisture areas of western Tigray is not yet conducted so that identification of optimum population and sesame varieties in the study area becomes relevant. Therefore, this study was conducted to determine the yield performance of three sesame varieties at different plant population to develop plant population recommendations for sesame production in optimum moisture areas of western Tigray, northern Ethiopia.

2. Materials and Methods

The experiment was conducted during 2018 cropping season in the optimum moisture areas of western Tigray at "*Zuria-Dansha*". The site is located at geographical coordinates of 13o 38' 306" North latitude and 36o 52' 84.1" East longitude and altitude of 747m.a.s.l. According to meteorological agency record the area receives mean annual rainfall and temperature of 888.4 mm and 28.7 °C, respectively. The experiment consisted of two released sesame varieties (Gida-Ayana, and Setit-2) and one local Hirhr and four plant population. To achieve the required planting density per ha, the intra and inter row spacing were placed in brackets, respectively. The plant populations were 80,000 plants/ha (20 cm × 60 cm), 124,444 plants/ha (15 cm ×50 cm), 250,000 plants/ha (10 cm × 40 cm) and 666,666 plants/ha (5 cm × 30 cm and there were 6, 7, 9 and 12 rows in each plot, respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications where each plot size was 9 m^2 (3.6 m width by 2.5 m length) having between plots and blocks distance of 1 m and 1.5 m, respectively. Seeds were manual drilled in rows and urea fertilizer (50 kg/ha) was applied in split applications (half at sowing and half before flowering) while DAP (100 kg/ha) fertilizer was applied only at sowing time. All plots were weeded as per the recommendation. When the plants attained height of 10 to15 cm, seedlings were thinned out to the specified distance between plants to obtain the required plant population. Harvested plants from each plot were separately kept in sacks for drying for two weeks and threshed manually. All other agronomic practices were kept normal and uniform for all treatments.

2.1. Data collected. The following agronomic data were recorded from the central rows of each treatment.
(i) Number of fertile capsules per plant (NFCPP): The mean numbers of capsules obtained from 10 pre-tagged plants at harvest.
(ii) Number of seed per capsule (NSPC): The mean numbers of seeds per capsule were obtained from 10 randomly taken plants at harvest by taking three capsules per plant.
(iii) Thousand seed weight (TSW): weight in grams of 1000 randomly chosen seeds. Seed yield (kg/ha):
(iv) Seed yield (kg/ha): the total seed yield (kg/ha) harvested from the net plot area
(v) Oil content (%): Determined from 40 gram samples taken from each treatment using Nuclear Magnetic Resonance

2.2. Data analysis. The recorded date were analyzed using statistical software of GenStat-18 for the analysis of variance and Duncan's Multiple Range Test (DMRT) was used to separate differences among treatment means at 5% and 1% probability level.

3. Results and Discussions

3.1. Variance Estimation of Yield and Yield Related Traits. The results of yield and yield related traits obtained from the analysis of variance (ANOVA) of the sesame varieties and plant population are described in Table 1. The variety, plant population, and variety by plant population interaction variances were decomposed to provide a general overview in relation to the yield and yield related traits of sesame varieties planted with different plant population. As a result, variety × plant population interaction showed statistically significant variation ($p < 0.05$) for seed yield. However, only the main effect of variety and plant population were statistically highly significant ($p<0.001$) for the traits: number of fertile capsule per plant NFCPP), number of seeds per capsule (NSPC) and thousand seed weight (TSW). The described statistical difference was due to both the main and interaction effect of sesame varieties and plant population. As indicated in Table 3 below, the varieties and plant population were clearly different (highly significant for both main effects) in their yield and yield related traits, in which the experiment was conducted. This might be due to the variations of adoptability of the varieties to the soil and climatic conditions of the experimental area and differences in nutrient utilization of the different plant population in optimum moisture areas.

Table 1: Mean squares values for different agronomic traits of sesame varieties planted with different plant population

Source of Variation	**DF**	**Seed Yield (kg/ha)**	**NFCPP**	**NSPC**	**TSW (g)**
Replication	2	3105	7.41	62.66	0.17361
Varity	2	70730**	813.22**	1887.65**	0.337**
Plant population	3	28128**	546.45**	363.77**	0.344**
Varity × Plant population	6	5186*	20.49ns	23.13ns	0.065ns
Residual	22	1761	23.61	46.98	0.039

DF: degree of freedom; NFCPP: number of fertile capsules per plant; NSPC: number of seeds per capsule; TSW (g): thousand seed weight in gram; ns: non-significant (p<0.05); * significant at p<0.05; ** highly significant at p<0.01.

3.2. Number of Fertile capsules per plant. The analysis of variance indicated that highly significant differences (p<0.01) were found among the main effects of sesame varieties and plant population, their interaction for number of capsules per plant was not statistically significant (Table 1). The highest number of capsules per plant (44.17) was obtained for variety Gida-Ayana planted while the variety Hirhr gave the lowest number of capsules per plant (27.89) as indicated in Table 2. The maximum number of capsules per plant obtained might be attributed to the genetic difference of the varieties and the suitable agro-climatic conditions for the new variety Gida-Ayana. As described by Valiki et al. (2015), significant differences were found among sesame varieties in the number of capsules per plant due to the genetic difference of the varieties. The result is also corroborated with Begum et al. (2001) who reported that, there is a variation in number of capsules per plant evaluated for different sesame varieties due to the existence of suitable climatic conditions for the varieties in the tested area.
The effect of plant population on number of capsules per plant on the other hand showed that, the highest (44.07) was recorded from sesame grown at the lowest plant population while the lowest (26.01) was recorded from sesame grown at the highest plant population. The increment in the number of capsules per plant as the number of plants per unit area decreases shows the importance of plant population in determining the number of capsules per plant; it may be due to optimum air movement and low competition for nutrients. This finding is in line with Mohhamed and Hamidu, 2018 who reported that effect of spacing was significant; 20x70 cm spacing had the maximum number of capsule whereas 20x40 cm spacing had minimum number of capsule. It was also reported that lower plant density increases number of capsules per plant in sesame Ahmed et al. (2002).

3.3. Number of seeds per capsule. The main effect of variety and plant population showed highly significant (p<0.01) effect on number of seed per capsule while the interaction effect of variety and plant population was non-significant (Table 1). From among the varieties, the highest number of seed per capsule (72.58) was obtained from the variety Gida-Ayana and the lowest from variety Hirhr (48.25) (Table 2). This could be due to the inherent genetic variation existing in the varieties. Both Kathiresan (2002) and Begum et al. (2001) reported similar findings, sesame varieties differed on number of seeds per capsule. A research done by Gabisa et al. (2015) also found that groundnut varieties varies in number of seeds per pod and the authors explained that number of seed per pod is mainly influenced by genetic factors found in the different varieties than agronomic practices.

The highest number of seed per capsule was recorded at the planting density of 80,000 plants/ha. On the contrary, the lowest number of seed per capsule was recorded at planting density of 666,666 plants ha-1 (Table 1). This could be due to the increase in plant density and increased intra specific competition, which eventually caused reduction in the number of seeds per capsule in the highest plant population. These findings corroborated with the report of Caliskan et al. (2004) who found that the maximum number of seeds per capsule was recorded from lowest plant population (102,000 plants/ha) while lower value of seeds per capsule was recorded from highest plant population (512,000 plants/ha). Similarly Roy et al., 2009 reported that with the increase of row spacing number of seeds per capsule increased. In contrary, number of seeds per panicle was not affected by change in plant density Kale et al. (2018).

3.4. Thousand Seed Weight (g). The analysis of variance revealed that the main effect of variety and planting density on thousand seed weight of sesame was highly significant (p<0.01) but not the interaction (Table 1). The highest thousand seed weight (2.3g) was observed for variety Setit-2 which is at par with variety Gida-Ayana which had thousand seed weight of 2.2g and the lowest 1000 seed weight was recorded for variety Hirhr (1.97g) (Table 2). The reason might be due to the genetic makeup of the variety as described by Govindarasou et al. (1998). This result is in agreement with Sivangamy and Rammohan (2013) found that 1000-seed weight was affected by sesame varieties.

The planting density of 80,000 plants ha/ha recorded the highest thousand seed weight (2.3g) which is at par with planting density of 124,444 plants/ha whereas the lowest thousand seed weight was obtained from planting density of 666,666 plants/ha followed by planting density of 250,000 plants/ha (Table 2). At lower planting density, there would be improved accumulation of food ingredients in the seed due to the optimum availability of nutrients and water, optimum air movement in the plant micro-climate; this helps the weight of 1000-seeds to be increased. This result is in agreement with that of Lakew et al. (2018) who reported that thousand seed weight decreased as plant population per unit area increased. The inter-row spacing of 40 cm and 3.5 kg seeding rate recorded highest seed weight (3.56 g) than with same row spacing and 6.5 kg seeding rate (3.06 g) in sesame. Significant difference was also observed in plant density effect on hundred seed weight of haricot bean by Abate (2003). Hundred seed weight was decreased with increase plant density. On the other hand, non-significant difference was also reported in different sesame plant population for 1000-seed weight by Valiki et al. (2015) and Ahmad et al. (2002).

3.5. Oil Content (%). The main effect of variety exerts highly significant ($p<0.01$) effect on oil content of sesame. However, there is no significant difference in planting density and interaction effect on oil content of sesame varieties planted with different plant population (Table 1). The genetic difference of the varieties may provide different seed oil content percentage. The variety Gida-Ayana recorded higher seed oil content (52.74%) while the lower seed oil content of 46.99% was recorded in the variety Hirhr (Table 2). Seed oil content of sesame varieties were not affected significantly by the various planting densities under study. However, increasing planting density decreases seed oil percentage. May be the lower number of plants per unit area helps the growth of plants that are good for the availability of nutrients, air movement, decrease disease development, thereby increasing the accumulation of food ingredients in seeds as part of oil content of seeds. Similar findings were reported by Valiki et al., 2015, sesame cultivar had significant effect on oil percentage while plant density had no effect on oil percentage and the authors reported that although plant density did not affect oil percentage of sesame cultivars, but as plant density increases oil percentage of the cultivars decrease. According to Rahnama and Bakhshandeh (2006), seed oil percentage increases as plant distance increase up to 60 cm.

Table 2: Effect of planting density on number of capsules per plant (NFCPP), thousand seed weight (TSW), number of seed per capsule (NSPC) and oil content (%) of sesame at *Kebabo* during 2018 cropping season

Variety	NFCPP	TSW (g)	NSPC	Oil content (%)
Gida-Ayana	44.17^{a}	2.3^{a}	72.9^{a}	52.8^{a}
Humera-1	33.97^{b}	2.1^{ab}	61.3^{ab}	47.2^{c}
Hirhr	27.89^{c}	1.8^{b}	47.3^{b}	46.8^{c}
LSD (<5%)	4.11	0.17	8.80	0.80
Plant population				
80,000 plants/ha	44.07^{a}	2.33^{a}	58.53^{a}	47.02^{a}
124,444 plants/ha	38.69^{b}	2.00^{ab}	47.30^{b}	47.3^{a}
250,000 plants/ha	32.56^{c}	1.80^{b}	46.00^{b}	46.83^{a}
666,666 plants/ha	26.01^{d}	1.77^{b}	41.2^{b}	46.80^{a}
LSD (<5%)	4.75	0.19	6.70	0.9
CV%	13.8	9.3	11.0	1.9

LSD: Least significance difference; CV (%): Coefficient of variation; Means of the same letters are not significantly different at 5% level of significance.

3.6. Seed Yield (kg/ha). The analysis of variance showed that highly significant difference ($p<0.01$) were found for the main effects of varieties and plant population whereas, the interaction effect of variety and plant population on seed yield (kg/ha) was significant ($p<0.05$) (Table 1). The highest seed yield (656.7 kg/ha) was obtained for variety Gida-Ayana with 250,000 plants/ha (10 cm × 40 cm) while the lowest seed yield (383.7 kg/ha) was obtained for variety Hirhr with 80,000 plants/ha (20 cm×80 cm) (Table 3). The higher seed yield in variety Gida-Ayana with 250,000 plants/ha might be attributed to higher yield potential of the variety and efficient use of resources in the 250,000 plants/ha and the variety might be adapted to the climate and edaphic factors of the tested area. Since the variety was released from areas of high rain fall and temperature by Assosa Agricultural Research Center (ASARC), the similarities of climate conditions of experimental area with Assosa might be provided maximum seed yield than others. This finding is in line with Roy et al. (2009) who reported that the interaction effect of variety and row spacing was significant and as row spacing increases from 15 cm to 30 cm, the yield also increases depending on varieties but decreases at the highest row spacing (low plant population). The authors concluded that variety BINA Til planted at 30 cm row spacing obtained highest yield of sesame than 45 cm row spacing. Other study by Gabisa et al. (2017) also found that interaction effect exists on variety and plant density in groundnut, the highest seed yield was recorded from variety Tole-1 sown at plant density of 250,000 plants/ha while the lowest seed yield was obtained from variety Fayo sown at lowest plant population (142,857 plants/ha).

Table 3: Interaction effect of sesame varieties and plant population on seed yield (kg/ha) in optimum moisture areas of western Tigray during 2018 cropping season

Variety	plant population (plants/ha)	Seed yield (kg/ha)
	80,000 plants/ha (20 × 80 cm)	426.3^{de}
Gida-Ayana	124,444 plants/ha (15 cm×60 cm)	568.5^{b}
	250,000 plants/ha (10 cm × 40 cm)	656.7^{a}
	666,666 plants/ha (5 cm× 20 cm)	583.7^{b}
	80,000 plants/ha (20 × 80 cm)	413.7^{de}
Humer-1	124,444 plants/ha (15 cm×60 cm)	528.2^{bc}
	250,000 plants/ha (10 cm × 40 cm)	535.1^{bc}
	666,666 plants/ha (5 cm× 20 cm)	485.9^{cd}
	80,000 plants/ha (20 × 80 cm)	383.7^{e}
Hirhr	124,444 plants/ha (15 cm×60 cm)	417.7^{de}
	250,000 plants/ha (10 cm × 40 cm)	428.5^{de}
	666,666 plants/ha (5 cm× 20 cm)	392.3^{e}
LSD (<5%)		71.06
CV (%)		8.7

LSD: Least significance difference; CV (%): Coefficient of variation; Means of the same letters are not significantly different at 5% level of significance.

4. Conclusion and Recommendation

The present research findings showed that the main effect of varieties and plant population were highly significantly differed in yield related traits. The variety Gida-Ayana recorded maximum fertile capsules per plant, thousand seed weight, seed per capsule and oil content (%) while the local variety Hirhr recorded the least. Similarly, fertile capsules per plant, seed per capsule and thousand seed weight were highest in the low plant population than highest plant population but oil content (%) was not affected by different levels of plant population. On the other hand, seed yield (kg/ha) were significantly influenced by the main effect of variety and plant population and their interaction effect. The maximum seed yield of 656.7 kg/ha was obtained from variety Gida-Ayana with 250,000 plants/ha (40 cm × 10 cm) which significantly increases yield by 34.75% as compared with local variety Hirhr with the same plant population. Hence, it can be concluded that higher seed yield and oil content (%) of sesame could be obtained by using Gida-Ayana variety sowing at the plant population of 250,000 plants/ha (40 cm × 10 cm) under optimum moisture areas of western Tigray and similar agro-climatic conditions.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding to publication of this paper.

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